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AVAILABILITY AND MARKETS OF STRUCTURAL INDUSTRIAL MINERALS IN SASKATCHEWAN

by

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Sources of production and consumption data: Statistics Canada, Energy Mines and Resources Canada

EXECUTIVE SUMMARY, OUTLOOK, & RECOMMENDATIONS

This study was undertaken to gain preliminary information regarding the availability and markets of selected structural industrial minerals in Saskatchewan. The information was derived from presently available data and reports. The present status of these commodities has been reviewed and an outlook for these commodities has been proposed.

The structural industrial minerals reviewed included: clay (including bentonite, bloating, brick, kaolin, ball, and fire) and their related clay products; sand and gravel; gypsum; limestone (lime, and cement); building stone; and silica sand (Figure 1).

CLAYS

Bentonite

Canada has imported approximately 350,000 metric tons of bentonite annually. The bulk of this material is used for pelletizing iron ore in central and eastern Canada, and by the oil and gas industry as drilling mud.

Although Saskatchewan has deposits of semi–swelling and non–swelling bentonite, significant increases in the development of Saskatchewan bentonite resources are unlikely. The availability of superior western United States (Wyoming) drilling mud and the distance to iron ore pelletizing markets are significant impediments. Markets for non–swelling bentonite are relatively small.

Bloating Clays

Provincial reserves of material suitable for the production of lightweight aggregate are significant. Glaciolacustrine clays and cretaceous Bearpaw Shale are available throughout the southern portion of the province and have proven to be particularly suitable for this purpose.

As virtually all lightweight aggregate is used in concrete blocks and redi–mix concrete, the market depends on the demand for houses and light industrial buildings. Present production of lightweight aggregate is not expected to show significant growth.

Common Clay

There are ample reserves of material suitable for the production of clay brick in Saskatchewan. The current demand for brick is being met by Saskatchewan suppliers. Out of province markets (ie. Winnipeg, Calgary, Edmonton) for this material are unlikely due to transportation costs and the fact these markets are served by local brick producers. The outlook for clay brick in Saskatchewan is tied directly to the level of construction activity.

The demand for clay suitable for the production of sewer pipe is virtually nonexistent due to the use of plastic and concrete. Likewise, the market for clay flue liners is suffering from competition from substitutes (ie steel chimneys).

Kaolin

A definite bright spot exists in the future of Saskatchewan kaolin. Deposits of kaolinite rich sediments of the Cretaceous Whitemud Formation have been known for many years. Imminent improvements in the technology to improve kaolin brightness for paper filler and coater will impact positively on the development of Saskatchewan deposits. The prospects for replacing premium priced, imported paper filler and coating grades of kaolin, currently obtained in the USA (Georgia) are promising.

Ceramic uses of kaolinitic clay are also on the rise. The domestic consumption of ceramic floor and wall tile has been increasing at a rate of approximately 7% per year since 1976. Current market demand is in the order of 16 million square meters (Guillet & Joyce, 1987). With total Canadian production capacity at 4 million square meters, there appears to be significant opportunity for greater production for domestic markets.

AGGREGATES

Sand & Gravel

Sand and gravel resources in Saskatchewan, are sufficient to supply demand for years to come. There is however little or no potential for out of province trade due to transportation costs, as these markets are served by local producers.

Demand and pricing will depend on the magnitude of future construction activity. Depletion of the resource in areas close to major cities and conse–

quent increased haulage will result in increased haul costs in some local areas.

Crushed Rock

Because of remote location of material suitable for crushed rock aggregate, and the subsequent transportation necessary to bring the material to the markets, no definitive market for this product has developed in Saskatchewan. The current practice is to crush coarse glacial gravel deposits which are closer to markets. There is no compelling reason to believe that this practice will change.

BUILDING STONE

Until recently there has been no production of stone from bedrock sources in Saskatchewan. In 1989 a dolomite quarry was established, in northern Saskatchewan to provide hand split stone for a building on the University of Saskatchewan Campus. In addition preliminary investigations of deposits in the Creighton–Denare Beach area have revealed the presence of "marble" and granitic deposits of building stone quality.

Studies have indicated that the use of natural stone in construction is increasing and quality stone is able to command a premium price. Given the potentially high return for premium quality stone further investigation of these and other potential deposits are warranted.

SILICA SAND

Saskatchewan has ample reserves of silica sand. In terms of chemical and physical analyses these deposits can meet specifications for most applications, with some limitations. The market for blasting sand is shrinking due to stringent environmental regulations regarding this practice. Also, large increases in the requirements for cement are not anticipated in the near future. All other silica sand uses are expected to remain stable or grow slightly because of trends in the industries where they are utilized, with the exception of glass. Suppliers to the glass container industry are feeling the effects of competition from plastic and recycled glass.

Opportunities for the development of value added silica products should be investigated. In particular silicon carbide, silicon nitride, and specialty glass given the supply of rare earth elements which may be available form other mining operations in the province.

GYPSUM

Currently there is no gypsum production in Saskatchewan. The wallboard plant which operated in Saskatoon closed in 1988 and projections in construction activity do little to expect any reopening of this facility.

Development of the Egg Lake gypsum deposit remains unlikely due to expensive underground mining techniques necessary to extract the raw material, and the fact that relatively inexpensive gypsum and limestone are available from adjacent provinces.

LIMESTONE

Lime

There is no reported production of lime in Saskatchewan. Currently the use in the province is estimated at about 180,000 metric tons per year.

A deposit of high calcium limestone is known at Pinehouse Lake. Due to the northern location and the fact that expensive underground mining techniques would be necessary to recover the limestone, it is unlikely that lime produced from this material would complete well with Alberta or Manitoba product.

Cement

There is one producer of cement in Saskatchewan. The raw materials limestone and gypsum are imported from out of province sources. Clay, sand, and iron oxide are obtained from local sources.

Due to a downturn in the construction industry, there is not likely to be an increased demand for materials by Saskatchewan's only cement plant.

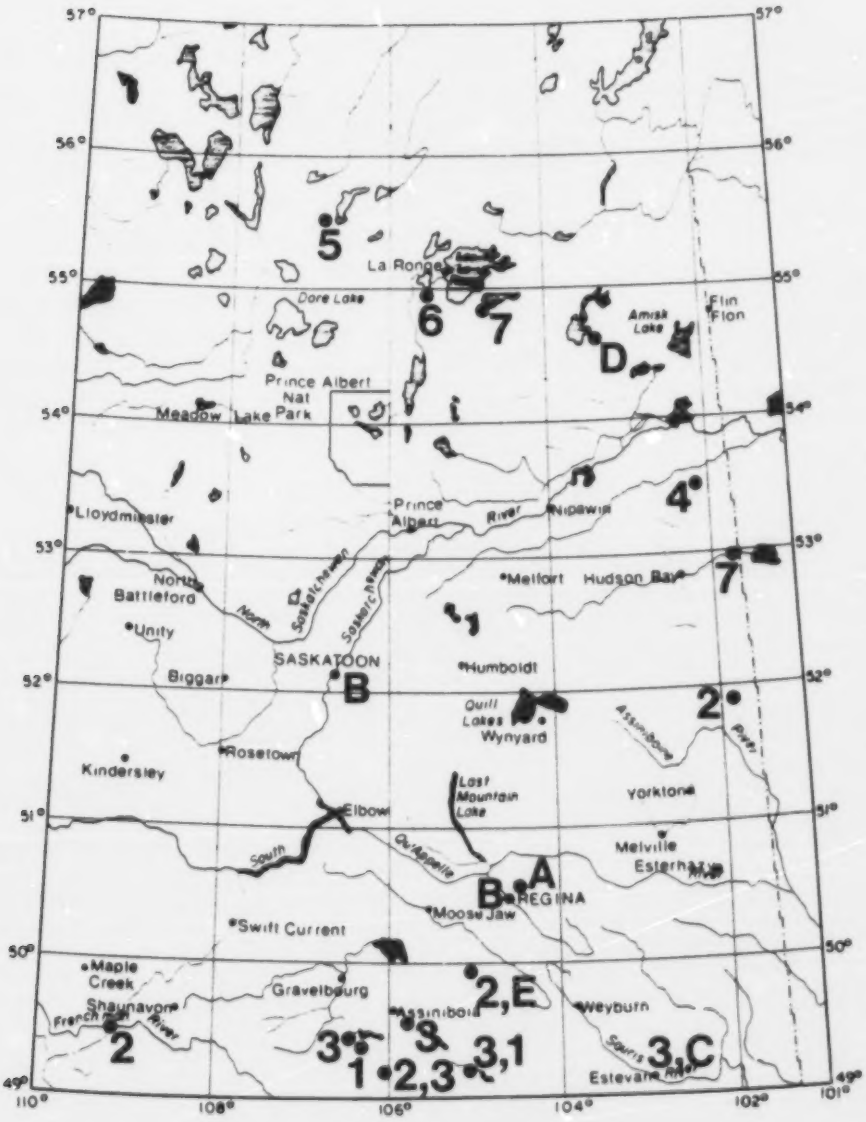

Figure 1: Location of Structural Industrial Minerals in Saskatchewan

Materials:

1 - Kaolin
2 - Bentonite
3 - Brick clay
4 - Cement rock
5 - Limestone
6 - Gypsum
7 - Silica sand

Production Facilities:

A - Cement
B - Lightweight aggregate
C - Building brick
D - Building stone (Dolomite)
E - Bentonite

(after: Guliov, 1984)

METHODOLOGY

The following steps will provide an outline of the procedures used in the study:

1. Database search of existing literature and reports of structural industrial materials in Saskatchewan and adjacent areas.

2. Pertinent information was extracted from the literature.

3. Review of Statistics Canada publications for available production and consumption statistics.

4. Tabulate and graph data presently available for production statistics.

5. Telephone calls to producers of the various commodities to establish current price levels.

6. Based on information compiled, commodities were assessed to determine an outlook for the future of these structural industrial minerals in Saskatchewan.

1.0 SASKATCHEWAN CLAYS

Saskatchewan has a wide variety of clay resources. The descriptions regarding these deposits and occurrences which follow are intended to define general depositional settings in which these resources occur. More complete and detailed descriptiон have been compiled by others. (Ries & Keele 1912, Davis 1918, Worcester 1950, Crawford & Carlson 1953, Carlson 1955, Hudson 1984, Masters 1986).

For all intents and purposes it is only economically viable to extract clay via surface mining techniques, therefore only deposits which are very close to surface will be discussed.

1.1 Bentonite

1.1.1 Saskatchewan Deposits

Occurrences of bentonite are numerous in southern Saskatchewan. The largest are in formations of Upper Cretaceous and Lower Tertiary age and occur in three areas of the province: in eastern Saskatchewan near Pelly; in the south–central part near St. Victor; and in the southwest near Eastend. In general they are thinner and exhibit a lower swelling capacity than the larger deposits in Alberta.

Northeast of Pelly, along the Swan River, a deposit of non–swelling bentonite occurs in the Pembina member of the Upper Cretaceous Vermilion River Formation. It has a light yellowish buff colour and one bed is about 0.5 m thick. Deposits are thought to be considerable but due to structural

deformation and lack of detailed drilling no estimate of the total reserve has been made.

One of the largest Saskatchewan deposits occurs along the Frenchman River valley, in the vicinity of Ravenscrag and Eastend. Here an extensive horizon of Upper Cretaceous semi–bentonite outcrops. Three seams of greenish grey bentonite with a total thickness of 3.5 m have been noted. It has been estimated that the deposit contains at least 2 million tons of bentonite.

Bentonite of the swelling variety is found in an area extending from the east end of Twelve Mile Lake to St. Victor and farther to the southeast in the Big Muddy Valley. These deposits are of Tertiary age and occur in the Ravenscrag Formation. Overburden varies up to several tens of feet in thickness but considerable bentonite is available under less than 6 m of overburden. The outcropping clay commonly has formed extensive caps on the shoulders of hills, particularly near St. Victor. The exposed surface is buff to steel grey but underlying bentonite is buff to greenish buff. Near St.Victor the bentonite horizon is, in places, up to 3 m thick. Immediately west of Pickthall the main bentonite horizon has an average thickness of 1.5 m. Estimates are that more than one million tons of bentonite are located in the area lying 28 km north of Pickthall, near Rockglen (Worcester 1950).

Swelling bentonite is produced by Avonlea Minerals from the Snakebite member of the Bearpaw Formation. Three seams of bentonite 61, 46 and 30 cm thick are separated by 365 cm and 182 cm of Bearpaw shale with little or no glacial overburden. Only in the Wilcox area are high swelling bentonite

sequences of the Snakebite Member thick enough to support an open–pit mine (Monea 1984).

1.1.2 Uses and Specifications

Select swelling bentonite is used as a binder in the production of pelletized iron ore concentrates. About 8 kg is used in every tonne of concentrate to provide pellets with enough green strength to withstand handling.

Bentonite is also used in drilling mud, principally to prevent the loss of drilling fluid into permeable zones by forming a mud cake on the wall of the drill hole. The bentonite also acts as a suspension agent to carry drill cuttings to the surface. The most critical specifications for bentonite drilling mud are suspension properties, wet–screen analysis, and moisture as shipped. Details regarding these specifications are outlined in American Petroleum Institute specifications API STD 13 and 13A.

Small quantities of bentonite are used as: plasticizer in abrasives and ceramic mixes; and as filler in paints, paper, rubber, pesticides, cosmetics, medicinal products and cleaning and polishing compounds.

Engineering applications are: in grout for sealing subsurface water bearing zones in dams and reservoirs; as additives to cements, mortars and concretes to suppress bleeding of the mixing water; as a compacting agent for gravels and soils; and as a ground stabilizing medium for excavating when used in a bentonite–water suspension. Bentonite slurry is also effective in fighting forest fires

Non–swelling bentonite, which has high adsorptive characteristics, is used in decolourizing mineral and vegetable oils, animal fats, waxes, beverages and syrups. In some countries it is used as a catalyst in the refining of fluid hydrocarbons (Shaw, 1987).

1.1.3 Production and Consumption

Avonlea Mineral Industries Limited is the sole Saskatchewan producer of bentonite. The company has a processing plant located in Wilcox ap–proximately 30 km south of Regina. Bentonite is excavated from deposits near Truax. It is sun dried and then hauled some 20 km to the processing plant at Wilcox for further drying and grinding.

Total bentonite production capacity in Canada was rated at approximately 131,000 tonnes per year in 1987. Of this amount Avonlea Minerals accounts for 60,000 tonnes of sodium type bentonite, while 36,000 tonnes of sodium type was produced by M–I Drilling Fluids in Alberta. The remaining 35,000 tonnes is a calcium type bentonite from Pembina Mountain Clays Inc. of Manitoba. The actual Canadian production for 1987 was reported to be 88,347 tonnes (Shaw,1987).

Consumption of bentonite on a national scale is reported to be approximately 250,000 tonnes per year. The bulk, approximately 55%, of this material is used for iron ore pelletizing. The foundry industry accounts for 23% of the national consumption, and the well drilling industry 20%.

Imports of bentonite to Canada are shown for the years 1980–88 (Figure 2). The USA supplied approximately 80% of the imported bentonite.

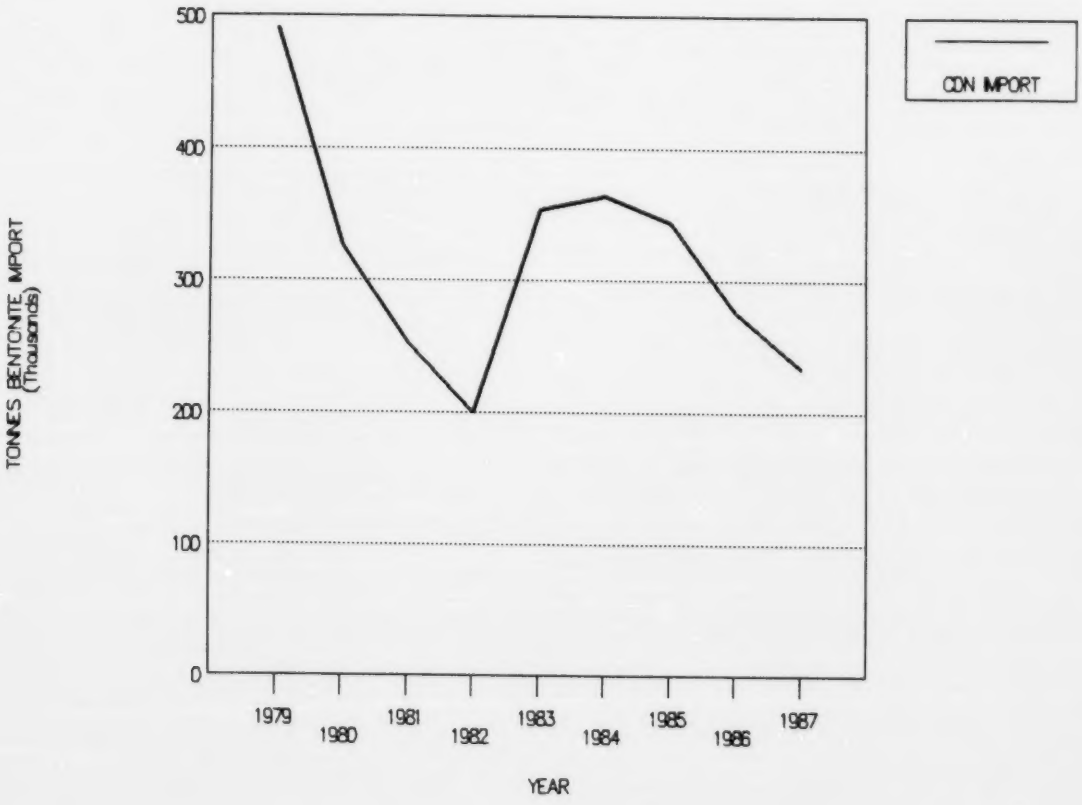

Figure 2. Canadian Bentonite Imports

Annual USA production capacity totals 5.7 million tonnes. Deposits in Wyoming and South Dakota account for more than two–thirds of the total United States production and are reported to be some of the world's most outstanding swelling bentonites. The bentonite beds are: relatively flat lying; continuous over large areas; and found in beds up to 9 m in thickness. The better grades of this clay have a yield value of more than 100 barrels/ton.

Bentonite is found in the Cretaceous and Tertiary formations in Alberta with the thickest deposits restricted to Upper Cretaceous Edmonton and Bearpaw Formations where beds up to 30 feet have been found. Alberta bentonite deposits are of the swelling and semi–swelling variety. Estimates of the total reserves of bentonite in Alberta are not known as operators do not determine reserves in detail beyond a 10 year supply. Magcobar Mining Company has estimated reserves of 2.3 million tons of swelling bentonite in the Rosalind area. Baroid of Canada estimates over 300,000 tons of swelling bentonite at Onoway.

Pembina Mountain Clays extract bentonite of the non–swelling variety from a deposit in the Cretaceous Vermilion River Formation on the eastern edge of the Manitoba Escarpment near Morden. This company produced approximately 18,000 tonnes of product a year. No estimate of reserves at this deposit was available.

1.1.4 Markets and Prices

Markets for Saskatchewan bentonite face stiff competition from superior drilling mud bentonite available from Western USA sources.

In 1986, 343,918 tonnes of bentonite were imported with a total value of $26,910,000 or $78.25 per tonne.

Demand for well drilling grade bentonite has been very volatile in the past. Assuming that the well drilling industry is now recovering bentonite consumption should begin to grow as drilling activity picks up. However, new mud systems using polymers may reduce bentonite consumption per footage drilled.

Bentonite used by the foundry industry is expected to experience moderate growth, over the long–term, of between 2–4% annually. A survey of the foundry industry in Ontario, where the bulk of the Canadian industry is located reports that even small changes in the chemistry and or grind of bentonite binders can have very significant effects on mould properties, and that the cost of bentonite is about 0.07% of the finished casting. Under these conditions a foundry is not likely to risk their production in order to gain the relatively small saving that may be gained by switching to a different sup–plier.

Demand for pelletizing grade bentonite is expected to decline over the next decade. Several North American iron ore plants have switched to organic binders and others have been testing various alternatives to ben–tonite as binders.

1.2 Bloating Clay

1.2.1 Saskatchewan Deposits

Practically any bentonitic clay low in carbonate minerals and clastics, either glacial–lake clays or bedrock shales, will make suitable feed for a lightweight aggregate plant. Pleistocene deposits cover extensive portions of Saskatchewan with a mantle of glacial and glacially derived sediments. The underlying bedrock in most of southern Saskatchewan consists of marine clay shales of Cretaceous age.

Saskatchewan glacial lake clays are especially high in expanding bentonite. Such deposits are well suited to the production of lightweight aggregate, a bloated product made by firing dried crushed clay in a rotary kiln to temperatures in the 1036–1120° C range (Hudson 1984).

Studies indicate that excellent results were obtained from tests conducted on shale from the Bearpaw Formation (Matthews 1957). The uniformity of this shale over large areas, and its excellent bloating properties make it one of the best sources of raw material for the manufacture of coated lightweight aggregate in the province. One of the best deposits of Bearpaw shale for lightweight aggregate occurs in the vicinity of Swift Current. Preliminary results showed the shale to be a good bloating clay with a wide vitrification range.

1.2.2 Uses and Specifications

With the exception of the ultra–lightweight materials produced from expanded vermiculite and perlite, lightweight aggregates are used primarily to

reduce the unit weight of concrete construction materials and to improve their thermal and acoustic properties. The single largest application is in the manufacture of concrete block, which consumes approximately 70% of the expanded clay produced in North America.

Specifications dictate that the dry, loose weight of structural lightweight aggregate ranges from 600 to 1100 kg/cubic meter, as compared to 2000 kg/cubic meter or more for sand and gravel. Details of these and other specifications can be found in the Canadian Standards Association (CSA) standard CAN–A23.1–M77 entitled "Concrete Materials and Methods of Concrete Construction". Specifications dealing with physical grading, densities, strength, and thermal conductivity of resulting concretes are outlined by Guillet (1987).

1.2.3 Production and Consumption

Lightweight aggregate was produced by Cindercrete Products Limited of Regina, and Apex Aggregate in Saskatoon. Apex Aggregates was purchased by Cindercrete in 1989, making them the sole lightweight aggregate producer in Saskatchewan. Both utilize glacial lake clay as a raw material for their product. It is interesting to note that in spite of the fact that deposits of superior bloating clays are known, the location of expanded aggregate facilities has been governed by proximity to market. Provincial production figures are not available.

1.2.4 Markets and Prices

The wide distribution of deposits suitable for lightweight aggregate results in markets being restricted to local consumers. Often plants will be situated as close as possible to an urban market where concrete demand is concentrated. In Saskatchewan the markets for lightweight aggregates are essentially restricted to Regina and Saskatoon. Out of province markets for this product are limited as the other major concrete markets in Manitoba and Alberta are served by local suppliers.

Average price for domestic clay lightweight aggregate, according to total Canadian production and value numbers from Statistics Canada, was approximately $24.00 per cubic meter in 1987. Currently lightweight aggregate produced in Saskatchewan is selling for $50.00 per cubic meter.

Given the rather depressed nature of the current Saskatchewan construction industry and the relatively limited markets for this product, the short term outlook for this material shows relatively slow growth.

1.3 Brick or Common Clay

1.3.1 Saskatchewan Deposits

A major deposit of clay which has been used as a brick or common clay source in Saskatchewan, is material from the Willow Bunch Member of the Paleocene Ravenscrag Formation. Near Rockglen, the Willowbunch Member is exposed in the disected uplands south of the Big Muddy Valley, and in the areas of Harptree, Big Beaver, Willow Bunch, Rockglen Strathallan and Wood Mountain. Some of the clays in these exposures are suitable

for ceramic tiles. Estevan Brick currently operates three clay pits in the Estevan area and one in Rockglen for raw material to produce red and buff coloured building brick. This company also extracts ball and kaolinized clays from the Whitemud Formation near Flintoft and Willows which is blended with other clay to produce white brick. The clays from the Ravenscrag Formation resemble Pleistocene, glacial lake, silty, clays as they fire at low temperatures over a narrow range to become a porous buff colored body.

The underlying grey clay is low in carbonates, and clay minerals tend to be of the expanding type. Clayey strata of this facies are difficult to work alone into brick by the customary stiff plastic process. This clay is used by Estevan Brick as a component of face brick bodies for the purpose of conferring high green dry strength on unfired ware (Hudson, 1984).

1.3.2 Uses and Specifications

1.3.2.1 Structural and Face Brick

The subclassifications of facing bricks are made on the basis of manufacturing processes. Products made by the extrusion of plastic clay material through a shaped die are called stiff–mud products. Bricks made by this method can be solid or cored if a bridge is placed in the die. Panel bricks are made in appropriate sizes and shapes to be used in the making of prefabricated panels which are then put in place as a complete portion of a wall. Sand–molded bricks, made by the soft–mud process are formed in damp wooden molds lined with sand to prevent sticking of the clay. Common and paving brick are a small part of the total brick production today.

Common bricks are not expected to be used for facing where they would be subjected to severe weathering conditions. They are most often available as off grade ware, as a result of production mistakes. Specifications established by the Canadian Standards Association for clay bricks define limits for compressive strength, water absorbtion and physical size.

1.3.2.2 Sewer Pipe and Flue Liner

Specifications for clay sewer pipe are stringent. Sewer pipe clays must be plastic, tough, have a high green and dry strength, and vitrify to a strong dense body of low permeability. Flue liners are made in various sizes from 8 to 24 inches square (20–60 cm). Specifications for clay flue liner are given in ASTM standard C315–78C which details the standard dimensions and acceptable tolerances. Sewer pipes are produced in 4 and 12 inch (10 and 30 cm) diameters and in 4 and 5 foot (120 and 150 cm) lengths. The market for vitrified clay sewer pipe has all but been lost to plastic and concrete pipe products.

1.3.3 Production and Consumption

The only Saskatchewan producer of brick or "heavy" clay products is Estevan Brick a Division of Thunderbrick Limited. Details of production and consumption figures were not available for the province, however total clay bricks sold in Canada amounted to 454,381, 655,499 and 634,971 for the years 1982–84 respectively. The total Manitoba, Saskatchewan, Alberta brick sales amounted, respectively, to 12.6%, 7.9% and 6.1 %. of this market.

1.3.4 Markets and Prices

Given the relatively low value/high bulk nature of the clay brick products, it is likely that this industry will continue to serve the Saskatchewan market only.

Current prices for Saskatchewan produced modular clay brick, range from $480.00 to $535.00 per thousand bricks, f.o.b. Saskatoon or Regina.

The decreasing proportion of the total brick market which the western Provinces hold indicates that materials other than brick are being used to a greater extent on the Prairies. Ontario, followed distantly by Quebec, accounted for approximately 88% of the total brick sales in Canada. Local suppliers of building brick in those provinces make the entry of Saskatchewan brick to the eastern Canada markets extremely unlikely, even without the increased transportation costs.

The alternatives to clay sewer pipe and flue tile (plastic pipe and stainless steel chimneys) have all but eliminated the markets for these clay products.

1.4 Kaolin, Refractory and Ball Clay

1.4.1 Saskatchewan Deposits

The following description of clay deposits in Saskatchewan is taken largely from Hudson (1984).

In the buff facies near the top of the Ravenscrag Formation is a pale bed, called the Willowbunch Member, containing much poorly crystallized kaolinite. It is 1.5 to 2.0 m thick. It is the most interesting part of the

Ravenscrag Formation for ceramics, and has been studied as a source of refractory clays and as a potential component of floor, wall and quarry tile.

The buff facies outcrops sporadically along the Boise' Couteau, but underlies heavy overburden and hence is not promising in that area. However, on the south slope of Wood Mountain in the Rockglen–Killdeer area, outcrops are more abundant and overburden is nearly absent. These clays, containing poorly crystallized kaolinite, quartz and fluxing micaceous matter, often vitrify in the 1150 to 1180°C range and hence are more suitable for stoneware and quarry tile than for refractories.

A pit in the clays of the Willowbunch Member has been opened by Estevan Brick west of Rockglen. This clay fires to a good red colour and has 3 to 5 per cent absorption at 1180°C. The principal clay mineral is b–axis disordered kaolinite. The clay bed, 3 to 3.7 m thick, is underlain by buff silts of the Ravenscrag Formation and overlain by 2 m of rusty cobble gravels of the Miocene Wood Mountain Formation. The unusual red–fired colours might have been derived by leaching and redeposition of iron oxide from the ocher–bearing cobble gravels.

The Whitemud Formation is the only Upper Cretaceous formation, besides the Alberta Cypress Hills deposit, that is a suitable source of ceramic raw material for plastic formed ware. The Whitemud Formation extends, in scattered outcrops from Eagle Butte at the east end of Cypress Hills in Alberta to the middle of the Big Muddy Valley in Saskatchewan.

Two kinds of sediment occur in the Whitemud Formation. The bulk of the formation consists of kaolinized sand, a mixture of quartz sand and

kaolinite with lesser amounts of mica, in massive layers up to 18 m thick. The kaolinite content may reach 50 to 55 per cent in some occurrences in the Wood Mountain area, but is usually less. It decreases downward and is absent at the interface with the underlying Eastend Formation.

The Upper beds of the formation consist of plastic clays of a fire clay or ball clay type, high in b–axis disordered kaolinite.

Towards the east and north edges of the area of occurrence of the Whitemud Formation, glacial thrust–faulting of clayey beds has reduced the formation to a series of fault blocks or to mere erratics in till.

Economically workable deposits of plastic clay are confined to a few regions. The most important of these is exposed along the meltwater channel between Willows and Readlyn. Many pits were worked here between 1915 and 1955 to produce ball and stoneware clays.

Another region of plastic clay deposits lies along Wood Mountain Creek, and includes the Flintoft pit of Estevan Brick. Smaller unopened deposits occur to the east along Gollier Creek. Further east, ball clays once were worked underground at the Midland Mine near the west end of Willowbunch Lake. Widespread deposits further down the Big Muddy Valley lie under excessive overburden. Fire clay was being mined by A.P. Green Refractories Ltd. from one of the numerous fault blocks near the Claybank fire brick plant. This same firm also worked a relatively flat–laying deposit in the Cactus Hills.

The remainder of the Cretaceous marine shales are precluded from consideration as a raw material for plastic formed ceramic ware because of their high montmorillinite content.

Nonmarine beds carrying kaolinitic clays reappear in the Lower Cretaceous in the Swan River (Blairmore) Group. Industrial usage of these clays has been limited to Manitoba for reasons of access. Attempts to produce face brick from kaolinitic stoneware clay near Swan River were short lived. Red River Brick and Tile of Lockport, Manitoba has opened pits near Ste. Rose du Lac to extract Swan River Group stoneware clay and the underlying kaolin–quartz mixtures and red–firing clay. In this plant, marine shales from the Pembina Mountain area and Pleistocene glacio–lacustrine calcareous silts are used as supplementary brick mix components.

Clays suitable for clay products are not found in Lower Paleozoic sediments or the igneous and metamorphic rocks of the Precambrian in Saskatchewan (Hudson, 1984).

1.4.2 Uses and Specifications

Kaolin is used in a wide variety of industrial applications. The properties which make it unique include: chemical inertness over a wide pH range; whiteness; good covering and hiding power when used as a extender in coated films and filling applications; softness and nonabrasiveness; low conductivity of heat and electricity; and a relatively low cost in relation to materials with which it competes. Some uses of kaolin require very rigid specifications including particle size distribution, colour, brightness, and

viscosity, whereas other uses require practically no specifications. The better grades of kaolin make up most of the tonnage sold. Many grades of kaolin are designed for specific filler uses, in particular paper, paint, plastics and rubber, in addition to its use in ceramic applications.

In Canada imported kaolin is used mainly in manufacture of paper where it is used for both filling and coating purposes. This accounts for about 80% of the total consumption. Kaolin is not used in the manufacture of newsprint. The most important specifications for the kaolin used in paper applications are brightness, particle size and particle size distribution, viscosity, and screen residue. In general a brightness of 70–85% is required for paper filler clay and ranges from 86–92% for paper coating clays. The more uniform finer grained material is used for coating while the kaolin composed of a wider range of particles is suitable as filler. Paper coating grade kaolin has a particle size of 95–100% finer than 2 microns, while filler grade particle size varies from 60–80% finer than 2 microns. Flow properties of kaolin are very important in paper coating because they affect the functioning of the coating operation as well as the final quality of the paper products. High quality paper grades should be as low as possible in coarse material, which is usually expressed as the residue failing to pass through a screen with 45 micron openings. Although the amount of screen residue doesn't reflect the quality of the fine material that pass through the screen, high grit is objectionable because of its abrasiveness and the fact that it is likely to mar the finish surface of the paper (Guillet & Kriens, 1984).

The kaolin used as filler in paint and plastic must meet certain electrical resistivity specifications. The resistivity test is designed to give an indication of the amount of residual salts that might be contained in the clay. The higher resistivity values reflect a low soluble–salt content. Kaolin is also used as a filler in the rubber industry for reinforcing or stiffening the rubber and as a low cost rubber pigment.

The ceramics industry uses kaolin in the manufacture of bone china, porcelain, stoneware, whiteware, sanitaryware, electrical insulators, and refractories and refractory aggregate. The most important tests for clays used in ceramic products are: modules of rupture (MOR), casting rate, pyrometric cone equivalent (PCE), fired colour, and shrinkage. The fired colour of kaolin is important because some burns white and some burns buff or slightly pink. This is a visual test, and the test specimen, fired to a predetermined temperature, is compared to a standard. Ceramic products undergo shrinkage at several different points in the manufacturing sequence specifically during drying and firing. It is important to know both drying and firing shrinkage. Linear and volume shrinkage can both be calculated but linear shrinkage is more commonly reported.

Ceramic floor and wall tiles traditionally have been made from mixtures of ball clay, sand, and fluxes. The mixtures are shaped by hydraulic press–ing or extrusion, and may be glazed or unglazed. In application they are fixed in place by adhesives, and joints are filled by coloured grouts. There are three basic tile forming processes: extrusion, Pressing, and casting. Extruded tiles are formed in a plastic state either individually or in pairs for

splitting. Dry pressing usually employs hydraulic presses, producing multiple numbers of tiles with each cycle. Casting uses molds and clay slips. The classification of tiles is based on end use rather than on the method of manufacture. All except thin floor tiles are formed by extrusion. Plastic and dry pressing are the methods used to produce floor and wall tile. Structural tiles are used for the construction of load bearing and non–loadbearing walls in buildings. Only a few partition tiles are made today because of the more common use of cement products for primary wall construction. There are many varieties of facing tiles all of which are designed for the construction of walls with decorative effects.

Fire or refractory clay is defined as detrital material, either plastic or rocklike, containing low percentages of iron oxide, lime, magnesia, and alkalies to enable the material to withstand temperatures of 1500°C or higher. Fire clay is basically compose of kaolinite but usually contains other clays such as diaspore, burley, burley–flint, ball clay, and bauxite. Fire clays occur commonly as clay below coal seams.

Specifications are based on pertinent physical and chemical tests to determine the properties of the clays, and the products made from them. The specifications for refractory clays are as many as the different uses. The most basic of these are: resistance to heat; and load–bearing strength at high temperatures. Most specifications will quote a pyrometric cone equivalent (PCE) which is a measure of the minimum duty required. Five classes of fire brick have been designated: Superduty (PCE 33), Highduty (PCE 31½), Mediumduty (PCE 29), Lowduty (PCE 15). Resistance to

shrinkage, spalling, cracking, and abrasion are also important in most applications.

Fire clays are used to produce commercial refractory products such as firebrick and blocks of many shapes, insulating brick, saggers, refractory motors and mixes, ramming and gunning mixes, and grog. Fire clay brick is used largely as lining in blast furnaces and ladles, which transfer molten metal between furnace and ingot molds. The primary steel industry in Canada consumes about 50% of all refractories (Boucher 1989). Fire clays are also added to other clays to increase the vitrification range.

1.4.3 Production and Consumption

Data regarding the consumption of kaolin in the province of Saskatchewan is not readily available. Consumption of kaolin in Canada is reported to be in excess of 300,000 tonnes per year. Prior to 1988 there was no reported commercial production of kaolin in Saskatchewan or Canada. Consequently, all Canadian kaolin requirements were supplied by imports, almost entirely from the USA, from the states of Georgia and South Carolina in particular (Figure 3). The Unites States leads the world in production of kaolin, contributing approximately 40% of the total, largely from mines in Georgia. Eastern Europe and the United Kingdom account for 25 and 16 percent respectively. Increasing production from Brazil is a significant new feature among world producers.

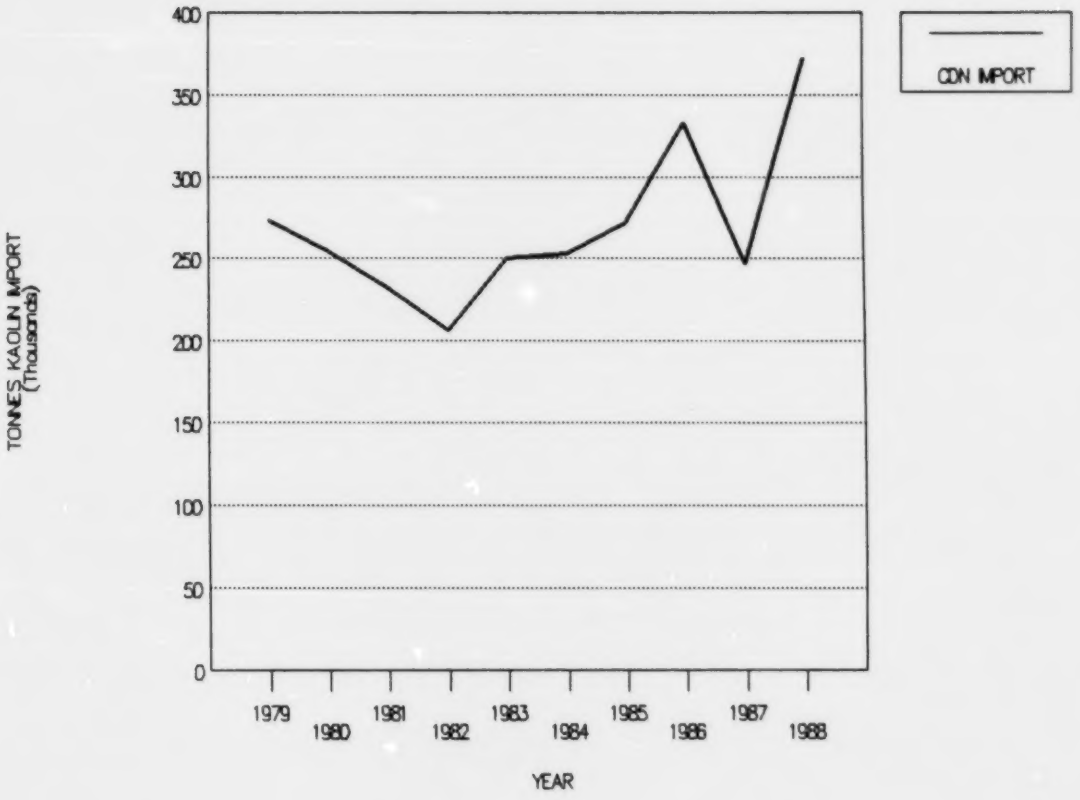

Figure 3. Canadian Kaolin Imports

Ekaton Industries Inc. of Calgary, Alberta, after proving reserves in excess of 200 Mt of kaolin in the Wood Mountain area of southern Saskatchewan, is proposing to build a plant with an initial output of 150,000 tonnes per year of filler grade kaolin product. Preliminary market research by Ekaton indicated that a Saskatchewan kaolin plant would have a definite transportation cost advantage, in the Western Canada and Northwestern United States market, over kaolin sourced in Georgia.

Statistics Canada also reported that two other properties are being investigated for the commercial production of kaolin. One is being investigated by Fargo Resources Limited and Brenda Mines Ltd., located in southern British Columbia, where 1 million tonnes of minable reserves of white filler grade and grey cement grade kaolin are indicated. In Ontario, James Bay, Kaolin Mines Ltd. is investigating a kaolin–silica sand deposit near Smooth Rock Falls, southwest of James Bay in northern Ontario. Proven reserves have been established at 63 million tonnes of ore.

The only producer of refractories in the prairie provinces was A.P. Green Refractories Canada Ltd., who utilized fire clay in the Claybank area to produce clay fire bricks. Production at this deposit ceased in 1989, although the company continues to produce refractory products and specialties from imported raw material at their Ontario facility in Weston. The Canadian consumption of refractory clays is declining because clay products which are low in alumina, are less refractory and less effective than high alumina–silica products (Boucher 1989).

1.4.4 Markets and Prices

There appears to be considerable potential for the further development of Saskatchewan kaolin resources, particularly as paper filler, and possibly coating applications as well as for ceramic uses particularly in the manufacture of floor, wall, and roof tile. Currently Saskatchewan plastic kaolinitic clays from the Ravenscrag Willow Bunch member near Rockglen, are being shipped to Thunder Bay, Ontario where they are used to produce split floor tile in a new facility recently opened there. Estimated Canadian tile consumption in 1985 was 12 million square meters, of which more than 90% was imported. The demand for ceramic tile has been growing at a rate of 7% per year (Guillet & Joyce, 1987).

Consumption of imported paper grade kaolin, almost entirely from the state of Georgia, continues to rise. Given the total lack of production of this commodity in Canada, there should be a viable Western Canadian and possibly Northwestern USA market for this material.

Prices for the many sub–grades of kaolin vary according to specifications. In general coating grades are more costly. About 89% of paper grade kaolin in the U.S. is either water washed, or water washed and delaminated grade. Both are used as filler and coater. "Industrial Minerals" (Sept. '89) lists the f.o.b. plant bulk price of coating clays as $US 120–192/ton while filler clays range form $US 64–92/ton. Calcined grades of kaolin (1988 f.o.b. Georgia) for kaolin as reported by Statistics Canada for paper coating grade kaolin was $450.00 US per short ton. Of all the kaolin used by the paper industry only 5% is calcined.1

Markets for refractory clay brick seem to have been lost to more refractory, superduty materials. The consumption of fire clay brick is declining because of their low alumina content which are less refractory and less effective than high–alumina silica products (Boucher, 1989).

The pricing structure of raw material to produce refractory products is very complex. Generally for alumina refractory products, the higher the alumina content the higher the price. In this market kaolinitic calcined clay, with its relatively low alumina content, commands the lowest price, but the refractories produced are in declining demand as they are of inferior quality.

2.0 AGGREGATES

2.1 Sand and Gravel

2.1.1 Saskatchewan Deposits

Sand and gravel deposits, in Saskatchewan, are for the most part a direct result of the last glaciation. During the Pleistocene period glacial ice advanced over the province from the northeast. Vast amounts of rock were eroded, crushed, and transported by the advancing ice sheet. When the ice began to receded high volumes of meltwater were released. This water was largely responsible for sorting the mixture of material which had been transported by the ice. Large deposits of sand and gravel accumulated in the proglacial environment as outwash plains and meltwater channel deposits. A great number of smaller deposits were formed as stagnant ice disintegration features; including kames, eskers, and crevasse fillings. Deposits of this type are generally smaller, more numerous and widespread, and are highly variable in composition. Kame complexes can be quite extensive and contain large amounts of usable aggregate.

Exploration and testing of hundreds of deposits by the Saskatchewan Department of Highways and others have shown that most deposits tend to be gravelly sand that is more than 50% sand with lesser amounts of gravel size material. Only about 1 in 10 deposits contains more than 50% gravel size material (ie <5 mm dia.). Moreover, even the coarse deposits usually contain relatively little material that is over 4 cm diameter.

It is difficult to generalize on the distribution of the thousands of sand and gravel deposits scattered throughout the province. In general, however,

it is likely that a few score of gravel deposits scattered widely across Saskatchewan contain more than 50% of the known gravel reserves. Smaller deposits will continue to be exploited as transportation cost is usually the critical factor to deposit development. The Saskatchewan Department of Highways has a data base which contains information regarding 1,379 sand and gravel deposits which they use as sources of material. These deposits tend to be situated close to highways and are concentrated in the southern half of the province. The apparent large number of deposits are not to be considered as all of the Saskatchewan occurrences of sand and gravel, but the number reflects the need to have deposits in many locations to reduce haul costs of the material to the point of use.

2.1.2 Uses and Specifications

Sand and gravel is used in its natural state as a base for buildings, road and railroad construction. In some instances, transportation routes are influenced by the location of the aggregate deposits so as to minimize haul costs.

Sand and gravel are used as aggregate for portland cement and asphaltic concretes, as sub–base under paving and as fill, particularly where good drainage is important.

Aggregate use in Saskatchewan for the year 1987 is shown in Table 1.

Table 1. Consumption of Sand and Gravel in Saskatchewan by Use

	Kilotonnes	%
Roads	8129	68.18
Railway Ballast	1315	11.03
Fill	925	7.75
Concrete aggregate	904	7.58
Backfill for mines	441	3.70
Mortar sand	82	0.69
Ice control	87	0.73

Specifications defining the quality of sand and gravel are variable depending on use. These specifications are normally concerned with: reaction of the aggregate to cycles of freezing and thawing; resistance to abrasion; particle shape; gradation; and deleterious components. Tests to measure the various physical properties of sand and gravel aggregates have been standardized by the American Association for Testing & Materials (ASTM).

An indication of the quality of sand and gravel can be determined by the amount of deleterious material found in the aggregate. Shale, ironstone, lime coatings, clay balls, weathered micaceous rocks, iron oxides, and chert are the most common deleterious materials. Shale is the most detrimental and widespread. It is particularly prevalent in the Estevan–Weyburn area and in the eastern portion of the province. This situation also prevails in other areas where meltwater channels have cut through the glacial drift and exposed shale along the sides and bottoms of valleys upstream of glaciofluvial deposits. If significant amounts of shale or other deleterious

materials are present, the deposit may be rendered uneconomic due to excessive beneficiation costs.

2.1.3 Production and Consumption

Production of sand and gravel for the period 1979–1988 is shown in Figure 4. Highway and building construction being the principle markets for sand and gravel, production is markedly affected by trends in those activities. In general, Saskatchewan production of this commodity has been increasing at a rate of about 4% per year. Due to the lack of detailed production and consumption statistics it is not possible to separate the amount of sand and gravel produced or excavated from that which is consumed or sold. Production and consumption are therefore assumed to be equal as stockpiled reserves are relatively constant.

2.1.4 Markets and Prices

Although deposits of sand and gravel are generally found throughout Saskatchewan not all are sufficiently extensive or of high enough quality to warrant commercial operations. Sand and gravel are low–priced commodities whose haul costs are often greater than the pit production costs. Large urban centers like Saskatoon and Regina have depleted those resources which are closest to the city and are now drawing on deposits which are more distant.

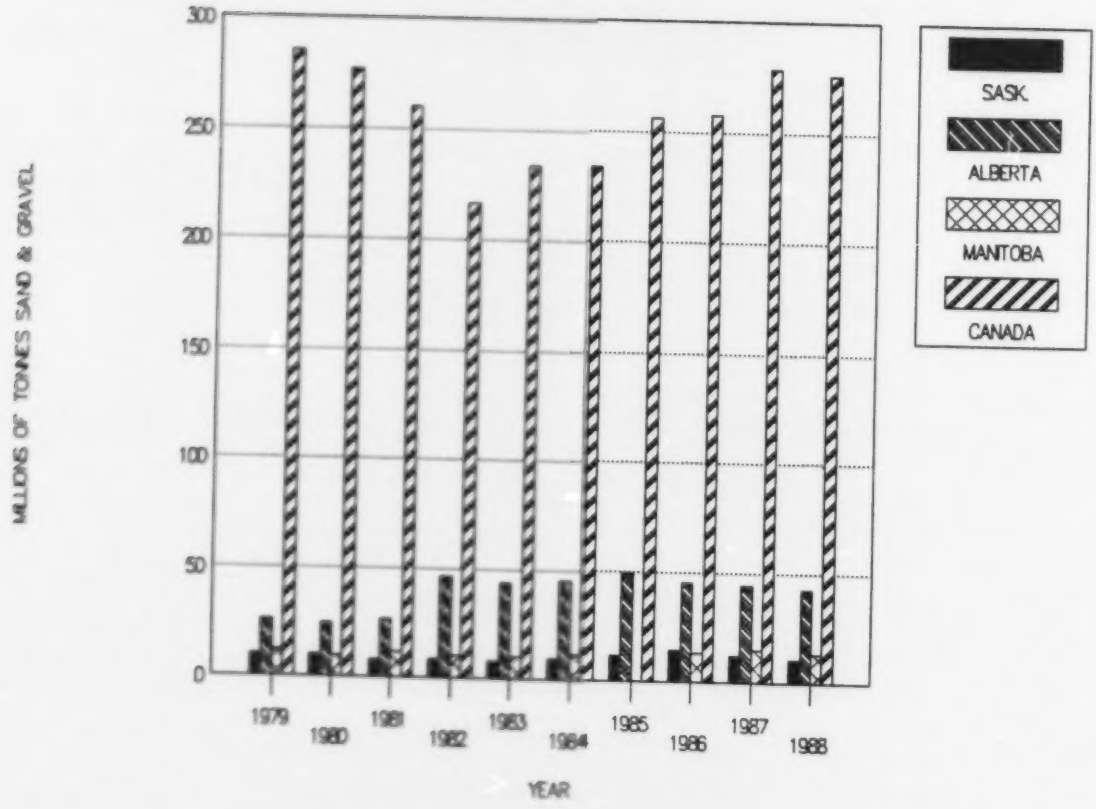

Figure 4. Sand and Gravel Production

The potential for out of province markets is poor, with the possible exception of deposits which are located such that transportation costs would be less than those of other suppliers in that region.

Prices for sand and gravel are variable from one place to the next. Prices are subject to production and transportation costs, by the degree of processing required and by the quantity of material required for a particular project. A study done by Saskatchewan Rural Development in 1986 (anonymous 1986) documented the highly variable nature of gravel prices. Prices paid by the 300 Rural Municipalities for delivered traffic gravel, ranged from $2.75 to $12.25 per cubic meter. The average cost was $6.09.

Current 1990 prices (f.o.b. Saskatoon, per cubic yard) from a local sand and gravel supplier were: pit run gravel $8.25; concrete gravel $13.50; pit run sand $7.00; plaster sand $11.50; and $20.00 for 2 cm crushed rock.

The final price of the material depends on production and transportation costs incurred. Cartage rates typically amount to $0.25 per cubic yard per mile ($0.31 per cubic meter per kilometer).

Sand and gravel will continue to be the single largest structural industrial commodity consumed in Saskatchewan. The general trend has been for aggregate production to rise at a rate of about 3% per year. Deposits close to major urban markets will become depleted and prices will rise as transportation cost escalate with increased haul.

2.2 Crushed Rock

2.2.1 Saskatchewan Deposits

The southern portion of Saskatchewan covering virtually all the inhabited area having agricultural importance, is underlain by soft shales and friable sandstones that are unsuitable as aggregate. Exposed carbonate rock suitable for crushed aggregate is located in the east central portion of the province where outcropping of Paleozoic sediments are found. Extensive outcrops of Precambrian material north of LaRonge would also be suitable material for crushed aggregate. The remote locations and expensive extraction and crushing costs relative to glacial deposits of sand and gravel has precluded development of bedrock aggregate.

2.2.2 Uses and Specifications

Crushed rock is used in a multitude of applications but it is used primarily by the construction industry as an aggregate in concrete, asphalt, road metal, and railway ballast. Crushed stone competes with sand and gravel as an aggregate material, and is subject to the same specifications as sand and gravel.

Construction aggregates are hard, essentially inert materials suitable for being formed into a stable mass either by the addition of cementing or binding materials that produce a concrete or by compaction to produce a road base or foundation. In Canada approximately 25% of all construction aggregate is derived from crushed stone, the remaining 75% coming from deposits of sand and gravel. The most common rock type used for crushed

stone is limestone/dolomite, which accounts for approximately 80% of the crushed stone production.

Specifications for crushed stone can vary widely depending on the use of the material and it is not uncommon for specifications to vary from one user to the next. However a series of tests to evaluate the physical properties of an aggregate have been standardized by the American Society for Testing & Materials (ASTM) which are widely used in Canada.

3.0 BUILDING STONE

3.1 Saskatchewan Deposits

With the exception of boulders transported by glacial ice, Saskatchewan's potential deposits of building stone are restricted to outcrops of the Precambrian Shield and Paleozoic carbonate rocks. The Precambrian Shield of Northern Saskatchewan presents a variety of rock types suitable for quarrying. A number of granitic plutons as well as deposits of Ordovician dolomites have had preliminary investigation with regard to their suitability as sources of building stone (Guliov 1989, Pearse 1990). These investigations have identified deposits of dolomite in the Creighton–Denare Beach area, which are finely crystalline and fossiliferous. The high polish taken by the dolomites qualifies them as "marble" in the building stone industry. Most of the investigations have concentrated on deposits which are located along road corridors in the southern portion of the shield.

This geological area has potentially suitable quarry sites. However, relatively few areas would have suitable geological uniformity and structure to ensure sufficient quantity for long term supply of stone that is free from fissures and fractures.

Key factors in the development of these resources are: access to transportation corridors; distance to markets; physical quality; large block size; uniqueness of product; and a high product to waste ratio.

3.2 Uses and Specifications

The principal uses of building stone are in construction and monuments. Building stone includes all natural stone used in building construction whether it be used for structural, curtain walls, veneer, floor tile or strictly ornamental use.

Rubble and rough construction stone, made up of rough–hewn granite or other stone, have long been used in such structures as retaining walls, sea–walls and bridge work. Requirements for such stone are that it resist weathering and erosion and that it breaks naturally into rectangular shapes that are easily set. Granite is well suited to these requirements, and is the most widely used stone for this purpose. Smaller sizes of broken stone have recently become popular as wall facing material in building construction, both for homes and small commercial buildings. The primary criteria is aesthetic, but ease of setting weather resistance, light weight, and ability to bond well to mortar are also important. The stone can be produced as a byproduct from other stone operations or it can be produced from small pits with a minimum of capital investment by small operators. The only requirements are that it find a market and that it can be easily and cheaply transported to that market.

Rubble is set in random patterns. The size of pieces range from 0.05 to 0.4 square meters of exposed rock.

Ashlar consists of rectangular pieces of stone of non uniform size that are set randomly in a wall. The exposed surface is generally less than 0.4 square meters. The surface may be sawed from quarry blocks that are not

suitable for finishing to cut dimension stone or may be made from rocks that break naturally into rectangular pieces.

Cut stone includes all building stone that is cut to precise dimensions on all sides. The surface may be textured, smoothed, or polished, but is always controlled and finished to specifications. In the industry this is known as dimension stone whereas rubble and ashlar are not.

Most dimension stone is used as curtain wall or veneer. The use of natural stone as structural members in buildings is almost non–existent in modern architecture, but columns, lintels, and other structural members may be faced with natural stone.

Granite, dolomite, and sandstone are generally used in slabs 70 to 125 mm thick. The stone is set as a non–loadbearing veneer with horizontal support at each floor and appropriate anchors to the structural wall behind. The load–bearing requirements of the stone are limited to self support for a floor height, despite the rather high requirements for compressive strength called for in the ASTM designations. Marble is more commonly cut to a thickness of 20 to 30 mm. The stone may be used as a facing on precast concrete or other structural backing material. Thin stone veneers offer two advantages: savings in the cost of the stone, and savings in weight which results in the use of less structural steel to support the stone. Because of the increase in the cost of structural steel, a recent development has been to cut granite into 30 mm thick slabs, thereby reducing weight.

A trend in the application of all kinds of dimension stone is towards use of larger slabs. It is not uncommon for dolomite and granite panels 3.7 m

long to be used in single floor to floor spans. Marble slabs are more limited in size, seldom exceeding 1.8 m but marble–faced panels backed with precast concrete may be produced in single floor to floor installations.

Because many of the large slabs are supported at the top and bottom only, wind load and other design specifications, relating the size of the panel to the thickness of the stone in order to give adequate strength are required. Furthermore, these requirements have put additional burdens on producers because no physical flaws in the stone can be tolerated. Whereas smaller size stones could be cut between flaws in a block, the quarrier is now called on to produce large, virtually flaw–free blocks of stone. Colour and pattern are inherent qualities of stone but they can be influenced by the finish. Rough textured surfaces tend to lighten colour and subdue patterns. Only granite and serpentine will keep a polished surface in exterior work. Polished marble is used extensively on interior walls where the natural colour and veining of many exotic marbles are used to advantage. In exterior work uniform colour and subdued pattern are achieved by flame treating granite. In the marble industry a textured surface is achieved with a steel rolling machine that rubs steel shot across the surface of the slab.

Monument stone encompasses a variety of products ranging from simple grave markers to statues, mausoleums, and elaborate structures. Standard specifications for building stone do not apply to monumental stone. The principal requirements are for uniformity of texture and colour, freedom from flaws, suitability for polishing and carving and resistance to weathering.

3.3 Production and Consumption

Saskatchewan production of building stone has been extremely limited with the exception of small–scale domestic use of glacially transported erratics or fieldstone. The first time Statistics Canada reported any production of stone in Saskatchewan was in 1987. Recently (1989) a dolomite quarry was opened to provide 8,000 tonnes of Saskatchewan stone for a building on the University of Saskatchewan campus in Saskatoon. This is the first reported quarry operation for building stone in the province.

The bulk of the domestic building stone production comes from Quebec and Ontario. The total Canadian building stone production and imports are shown in Figure 5. The bulk of Canadian building stone is quarried in Ontario and Quebec. Manitoba is the major western Canada supplier of granite and dolomite (Tyndall stone).

3.4 Markets and Prices

Prices for building stone range widely depending on the aesthetic qualities of the stone. Finished floor tiles (one square foot) range from $2.00 to $50.00 (Pearse, 1990). Using this range of prices a cubic yard of rock would have a potential value of between $648 and $16,800, assuming tiles of 1 inch thickness. According to Statistics Canada a tonne of rough building stone from domestic sources in 1985 was worth $37.79 while a tonne of rough building stone from imported sources was $174.45. Direct comparisons are difficult as so much of the price is related to aesthetic qualities.

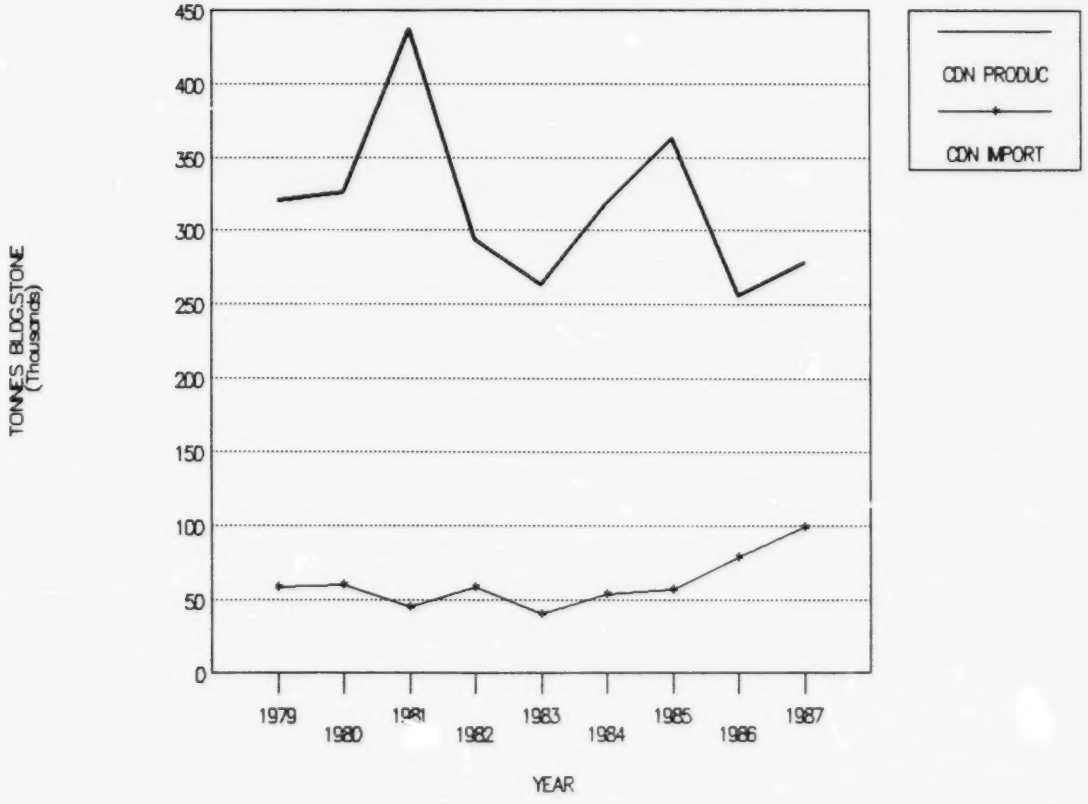

Figure 5. Canadian Building Stone Production

The use of granite and dolomite building stone is increasing in the Canadian construction industry. Imports of these materials are also increasing. Earlier reports have suggested that Saskatchewan building stone could be marketed successfully in Alberta, Saskatchewan and to a lesser extent in Manitoba (Guliov, 1982).

The market for marble is perhaps the most attractive given the relatively few producers in Canada and the growth in use of this materials. Annual consumption of marble in Canada and the United States is 250,000 tonnes rough stone equivalent. Finished stone equivalent is 40 million square feet. About 90% of this is imported from offshore, mainly Italy, the rest being derived mainly from two companies in the United States. A local source of marble penetrating this enormous market even marginally could easily double the current market demand for marble (Pearse, 1990).

4.0 SILICA SAND

4.1 Saskatchewan Deposits

Silica sand is the term applied to a sand that has a high silica content usually composed of the mineral quartz. These sand deposits are derived from the detritus formed by the mechanical disintegration of silicious rocks. Silica sand deposits are formed as the residual particles of rock are transported to new locations. The quartz particles, being very hard and resistant to abrasion, tend to accumulate and, as a result of selective sorting by wind and water form deposits of high–purity silica sand. Sand grains may be well rounded or angular depending on the amount of erosional action to which the grains have been subjected. There are a number of deposits of clean or fairly clean silica sand in Saskatchewan. These deposits are for the most part either undisturbed or reworked Swan River Sand, portions of the Upper Manville Unit of the Blairmore Formation, of Lower Cretaceous age.

The best known exposures of the Swan River Sands, are found along the Red Deer River near Armit. Here silica sand outcrops in the order of 9 meters thick covered by about 6–10 meters of overburden were identified. The upper 6 meters contain finer sand, typically in the 65–70 mesh range. The lower 3 meters of the deposit contain coarser sand typically between 28–48 mesh. Reserves have been estimated in the order of 14 million tonnes. Chemical analysis of the material is shown in Table 2.

Table 2. Chemical Analysis of Swan River Silica Sand (source: Babey)

SiO_2	97.40%
Al_2O_3	0.93
Fe_2O_3	0.07
TiO_2	0.06
CaO	0.04
MgO	0.09

The Wapawekka deposit is located approximately 45 km southeast of LaRonge, on the shores of Wapawekka Lake. This deposit is another outcrop of the Swan River Sand, but further north and more inaccessible. Reserves have been estimated in the billions of tonnes. This estimate includes material in the down dip direction of the deposit, which would be covered by greater thicknesses of overburden. Grain size analysis of a representative sample indicates 91% of the sand fell within 28–48 mesh. The results of chemical analysis from representative samples indicated that when compared to commonly used standards for chemical grade silica sand, iron is about three times too high and alumina ten times above acceptable levels.

In terms of economics the Wapawekka location has been considered too far from markets to justify transportation of other than top quality silica sand.

An Early Ordovician deposit of orthoquartzite, known as the Winnipeg Formation, occurs in the Hanson Lake area. The outcrop pattern of this formation is linear and follows the base of the Paleozoic escarpment. This high silica friable sandstone is capped by Ordovician dolomites. Samples

collected from this deposit have indicated a high degree of sphericity and roundness (0.7–0.9) and may prove to be a useful frac sand source (Byers).

4.2 Uses and Specifications

Naturally occurring silica sand is used in the manufacture of glass and fused silicaware. The silica content should be over 99% and the iron content should be uniform and less than 0.04%; other impurities such as alumina, lime and magnesia should be low. Uniformity of grain size is very important; glass sand should be between 20 and 100 mesh in size. Ordinary soda–lime glass, such as bottle, common tableware, and plate and window glass, contain from 65–70% silica.

Glass is made by fusing a batch composed of silica sand, soda ash, dolomite, nepheline syenite, and small proportions of other minerals in special furnaces.

Silica is used as a flux in the smelting of base metal ores. Silica is the active slagging ingredient, but impurities such as iron, alumina, and bases are not objectionable, but they reduce the percentage of silica available. In some cases it is more economical to use low grade silica in preference to more expensive high–purity silica.

Silica sand is used in the hydraulic fracturing of oil–bearing formations. This consists of pumping viscous fluid containing suspended sand into the oil bearing strata under pressure sufficient to cause fracturing and parting of the formation. When the pressure is released, the sand remains as a propping agent to hold the fractures open thus providing a permeable passage for the

flow of oil. The amount of sand used varies greatly but is generally from 2,500 to 7,500 kg per treatment. Sand used in the hydraulic fracturing of oil bearing formations must be clean and dry and have high compressive strength. It should have a high silica content and must be free of all acid–consuming constituents. The grain size of the sand must be closely con–trolled, usually between 20 and 35 mesh. The grains should be well rounded to facilitate placement and to provide maximum permeability. Recommended practices for testing sand for use in hydraulic fracturing have been established by the American Petroleum Institute (API) and are outlined in their report API RP 56.

Naturally occurring silica sand is used in the foundry industry for molding purposes. Silica sands for foundry use vary greatly in screen size and chemical composition. The purity and size of the sand used depends upon the type of casting to be produced and the foundry practice followed. Grain size is usually between 20 and 200 mesh in closely sized ranges. A sand with a round grain is preferred for this application.

Other uses of silica sand include: abrasive grit for sand blasting pur–poses; filtration medium in water filtration plants; and as an ingredient in the manufacture of portland cement. The chemical industry uses silica sand in the manufacture of such products as sodium silicate, silica gel, silicon carbide, silicon tetrachloride and a wide variety of silicones (McLaws, 1971). Sand used for these purposes must be of a purity similar to that used for glass, ie., >99% SiO_2.

Silica sand is evaluated for use on the basis of its composition and physical properties. The specifications for these properties vary according to the use to which the sand is to be put. Chemical composition is of paramount importance in glass making. Grain angularity and hardness are important for sandblasting. Roundness and strength are needed for fracturing sand. It is important to be aware that in some cases the specifications given must be considered general, and may have to be modified to meet the preference of the individual users. It is also possible that in some cases the specifications might be relaxed to permit the exploitation of more local, less expensive sources, although the general trend is for industrial sand specifications to become more stringent as the user demands greater uniformity and chemical purity.

4.3 Production and Consumption

Canadian silica production and consumption is shown in Figure 6. Production of silica sand in Saskatchewan has been reported by two companies. Hudson Bay Mining and Smelting Company Limited use silica rich sand deposits near Creighton, Saskatchewan as flux for their smelter in Flin Flon, Manitoba. Red Deer Silica Inc., of Saskatoon, has recently (1989) opened a silica sand deposit near Hudson Bay, Saskatchewan. The company has proven reserves in excess of 14 million tonnes from the Swan River group sediments. In addition to established silica sand markets Red Deer Silica is supplying specialty sand markets (ie. golf course bunker sand).

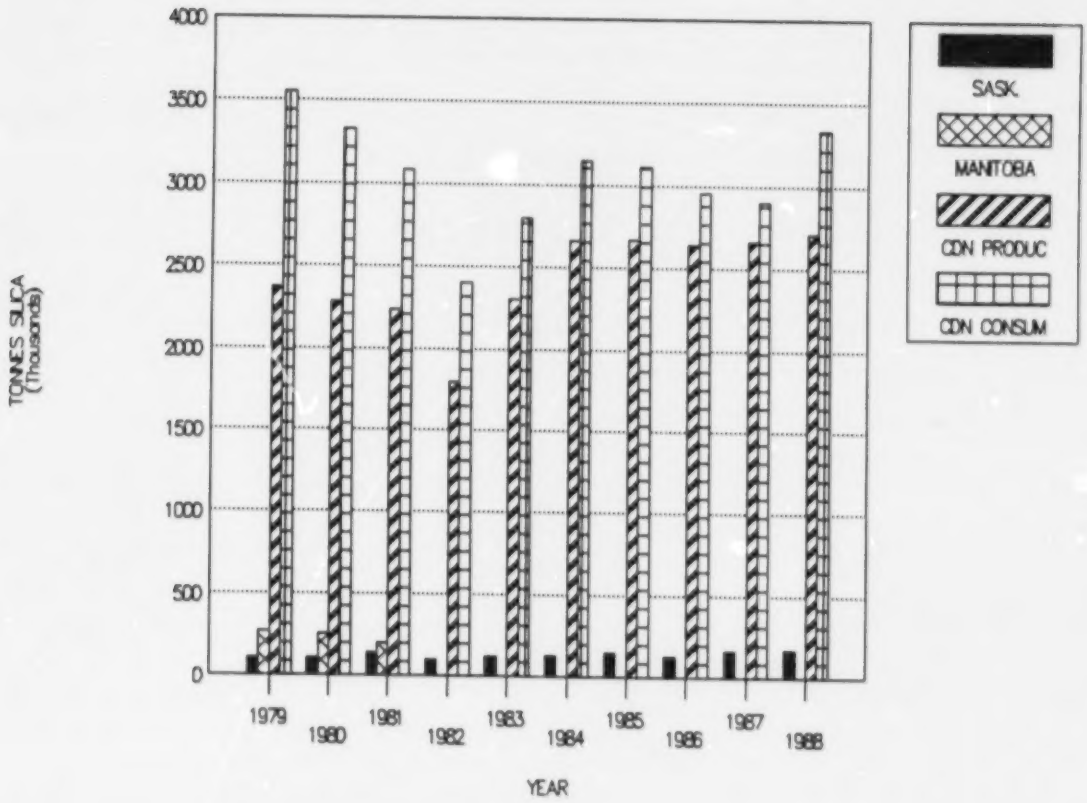

Figure 6. Silica Production and Consumption

A high–purity silica sand is produced in Manitoba from a quarry on Black Island, Lake Winnipeg, some 130 kilometers north of Selkirk. The silica sand produced is well rounded and suitable for use in foundries, glass and fiberglass. INCO Limited also produces a low–grade silica for its Thompson smelter from an impure quartzite formation. Production is reported to vary from year to year depending on nickel production.

In Alberta, Sil Silica produces silica sand from a sand in the Bruderheim area. This sand is sold mainly for fiberglass and sand–blasting material although it has also been used as a foundry, filtration, frac, and railway traction sand.

Additional investigation, beyond the scope of this study, regarding the opportunities which may exist in Saskatchewan for value added silica/silicon products, should be undertaken.

4.4 Markets and Prices

Current prices, obtained from one Western Canadian producer, for f.o.b. bulk silica sand, range from $43.00 to $25.00 per tonne depending on grain size.

Little improvement is expected in the Canadian glass container industry in the light of strong competition from plastics and recycled glass. The use of silica as a sandblasting material is also expected to decline as a result of environmental controls. Strong competition from both Manitoba and Alberta based producers may restrict out of province markets.

5.0 GYPSUM

5.1 Saskatchewan Deposits

The only reported significant occurrence of gypsum in Saskatchewan is found south of Egg Lake approximately 25 km southwest of LaRonge. A drill hole intersected a gypsum bed in the Lower Meadow Lake dolomite at a depth of 137.0 meters below surface. The bed consists of 85% gypsum and 15% dolomite and is 2.3 meters in thickness. This bed is overlain by a bed of dolomite with veins of gypsum 5.6 meter thick. Gypsum content in this bed is reported to be 25%. A similar unit 10 meters thick is found below the gypsum bed.

Current specifications for gypsum in the wallboard industry require approximately 80–85% gypsum depending on the impurities encountered. This requirement precludes consideration of other than the 2.3 meter bed which contained 85% gypsum. Currently there is insufficient data to calculate gypsum reserves for the area as there is only one drill hole intersection with no further information on lateral continuity.

Assuming a uniform thickness, and a tabular deposit, each hectare of this deposit would contain a total of 52,700 tonnes of gypsum.

5.2 Uses and Specifications

Gypsum is a hydrous calcium sulphate which, when calcined at temperatures ranging from 120° to 250°C, releases 75% of its chemically combined water. The resulting hemi–hydrate of calcium sulphate is commonly called plaster of paris. When mixed with water it can be molded,

shaped or spread and subsequently dried to form a hard plaster product. Gypsum is the main mineral constituent in gypsum wallboard, lath and tile.

Raw gypsum is crushed, pulverised and calcined to form stucco. This is mixed with water and aggregate and applied over lath to form interior wall finishes. Gypsum board, lath and sheathing are formed by introducing a slurry of stucco, water, foam, pulp and starch between two unwinding rolls of absorbent paper, the result is a continuous "sandwich" of wet board. As the stucco hardens, the board is cut to predetermined lengths, dried, bundled and stacked for shipment.

Crude gypsum is also used in the manufacture of portland cement where it acts as a retardant to control set.

5.3 Production and Consumption

At present no gypsum is quarried or mined in Saskatchewan. Canada however ranks second in the world in gypsum production with 8.5 million tonnes being mined in 1988. The bulk of this material, 6 million tonnes is mined in Nova Scotia, the remainder is produced by Ontario, Manitoba, and British Columbia (Figure 7). Total domestic consumption accounts for approximately 20% of Canadian production the remaining 80% being exported. Consumption of gypsum is closely tied to construction activity. A wallboard manufacturing facility which had operated in Saskatoon, was closed in November of 1988.

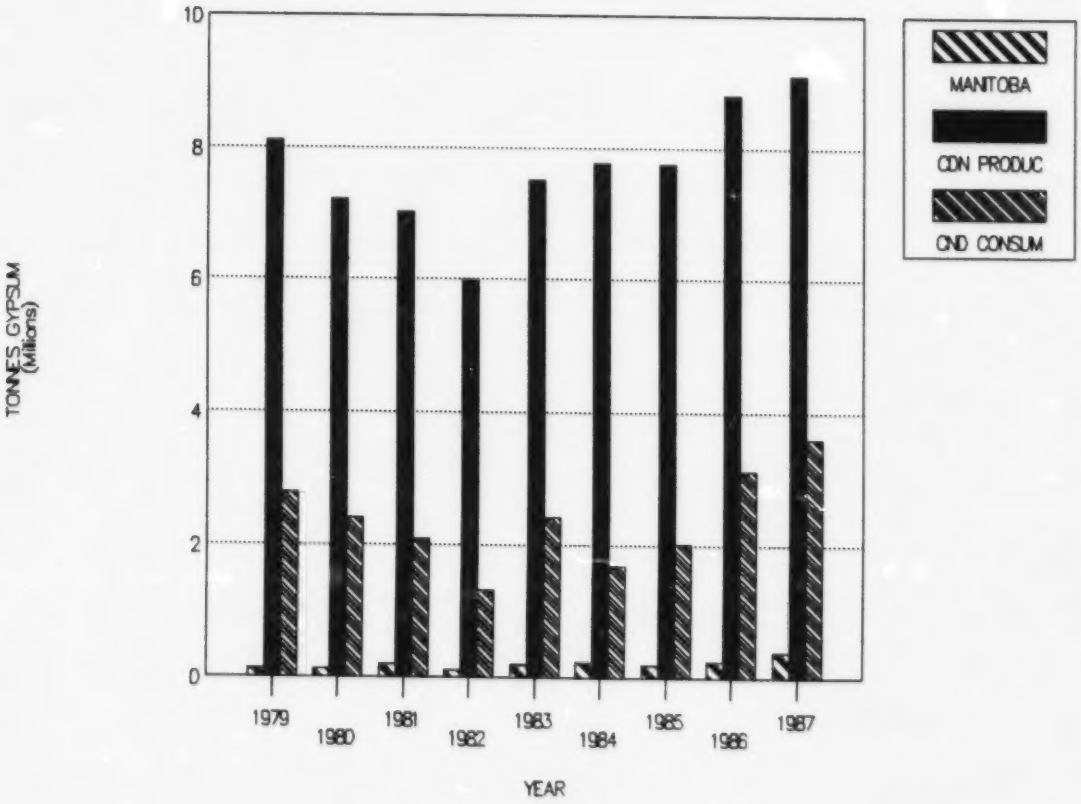

Figure 7. Gypsum Production and Consumption

Current suppliers of gypsum in the prairie region include Domtar Inc. who operate mines at Gypsumville and Amaranth in Manitoba and Westrock Industries Limited who produce mine gypsum at Amaranth Manitoba and Windermere, British Columbia.

5.4 Market and Prices

The major market for gypsum is the wallboard manufacturing facilities. Currently these are located in Winnipeg, Calgary, and Edmonton. Winnipeg is supplied with raw gypsum from open pit mines in Amaranth and Gypsum–ville. Calgary and Edmonton are supplied largely by on open–pit mine at Windermere, British Columbia.

The current f.o.b. price for raw gypsum ranges from $10.00 to $17.00 per ton. According to a feasibility study done by Kilborn Engineering (1978), on the development of the Saskatchewan deposit, the selling price for raw gypsum at that time would have had to be $25.00 per ton to break even. Given that the wallboard plant in Saskatoon has since closed, and the selling price for gypsum is still well below the break even price of 1978, the prospects for developing this deposit remain bleak at this time.

6.0 LIMESTONE

6.1 Saskatchewan Limestone Deposits

Limestone is a sedimentary rock composed predominantly of the mineral calcite ($CaCO_3$). A deposit of high–grade limestone of Middle Devonian age is located in the Pinehouse Lake area of northern Saskatchewan. The 10 meter thick deposit lies beneath approximately 67 meters of overburden. It is reported to grade about 54% CaO, 0.2% MgO, <0.5% SiO_2, and <0.2% Al_2O_3 (Guliov 1984).

The use of limestone depends largely on physical properties, chemical properties, or both. Physical properties are more important if stone is used "as is", such as for aggregate of building stone. Chemical properties are more important if the material undergoes changes from one form to another, such as the manufacture of cement or lime.

Specifications for carbonate rock should be considered generally as guidelines. For some limestone uses, minimum and maximum percentages of certain constituents are based on physical or chemical characteristics. Virtually hundreds of specifications exist for limestone and dolomite derived products. To list all of these specifications is beyond the scope of this publication. This investigation will concentrate on Saskatchewan limestone deposits suitable for the production of lime and cement.

Of prime importance to producers of these commodities is the cost of fuel. Energy requirement to produce one tonne of cement or lime are in the order of 4–6 gigajoules, depending on the efficiency of the kiln. A survey of provincial commercial gas rates indicates that fuel costs would be 5% lower

in Saskatchewan than Manitoba and 35% higher in Saskatchewan than in Alberta (all applicable taxes and discounts are included). This indicates a significant advantage to producers of these commodities in Alberta.

6.1.1 Lime

6.1.1.1 Uses and Specifications

Lime, generally speaking is a calcined or burned form of limestone commonly known as quicklime, calcium oxide, or when water is added calcium hydroxide or slaked lime. Lime is usually made from high calcium or high magnesium limestone, generally having a minimum of 97% combined carbonate content. Normally high–calcium limes contain less than 5% MgO. When the lime is produced from a high magnesium limestone the product is referred to as dolomitic lime.

Lime is used in many chemical and processing industries as well as construction and water treatment. The following are some of the major uses of lime:

a) Lime is used in uranium concentration, to control pH, to recover sodium carbonate, and to neutralize waste sludge.

b) In the pulp industry lime is used in the preparation of digesting liquor and pulp bleaching.

c) The metallurgical industry is the largest single user in such processes as the production of calcium carbide, calcium chloride, precipitated calcium carbonate, soda ash, iron pellets, and steel.

d) Lime is used in the treatment of domestic and industrial water supplies, for acid water treatment, and for waste water treatment.

e) Lime is used for soil modification and stabilization for road construction.

f) Lime is used in a variety of industries such as the manufacture of fertilizers, insecticides, sugar, pigments, glue, etc. (Gotts, 1979).

6.1.1.2 Production and Consumption

Saskatchewan has never reported any production of lime. Canadian lime production and consumption for the years 1979–1988 is shown in Figure 8. Significant consumption in the province is noted in the uranium milling, pulp and paper, and steel industries and has been estimated to be 187,000 tonnes per year. Lime is currently supplied to Saskatchewan consumers by Continental Lime Limited, a subsidiary of Steel Brothers Canada Ltd., which operates lime producing plants at Exshaw, Alberta and Faulkner, Manitoba. Continental operates a distribution terminal in Saskatoon which supplies the uranium milling operations in northern Saskatchewan. Significant amounts of lime are also used to produce precipitated calcium carbonate at a plant in Prince Albert. This material is used by the alkali process, Weyerhauser paper mill, as filler and coating material.

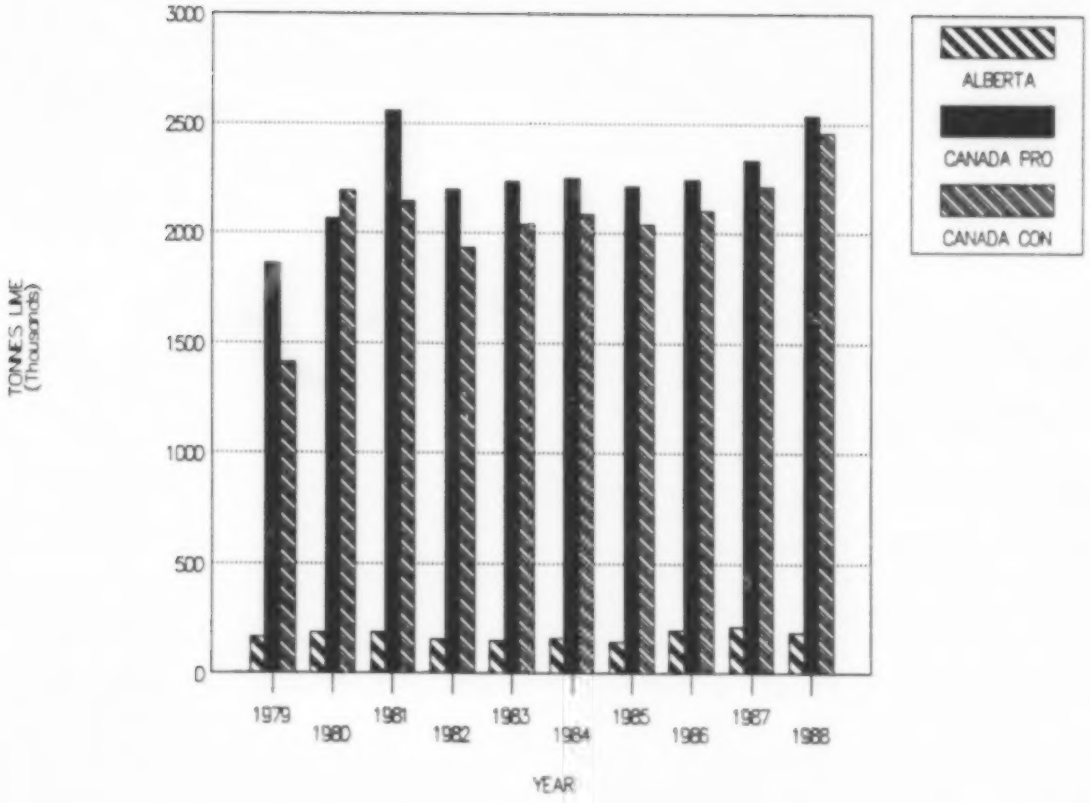

Figure 8. Lime Production and Consumption

6.1.1.3 Markets and Prices

The principal markets for lime in Canada are in the steel industry, the pulp and paper industry and the mining industry. Significant markets for lime in the environmental control field have yet to developed in Canada.

The possibility of the use of lime in water and sewage treatment and in the removal of sulphur dioxide from smelter gasses and from thermal power plant emissions is becoming more likely and may raise the consumption of lime by 25% over the next 5 years (Energy Mines and Resources, 1988).

The potential market in Saskatchewan for high calcium quicklime and hydrated lime was estimated to be approximately 182,000 tonnes (Lane, 1987). Out of province markets for lime produced in Saskatchewan would likely be difficult to enter given the presence of lime producers in both Alberta and Manitoba.

Current prices f.o.b. Exshaw, Alberta for quicklime and hydrate lime range from $91.00 to $147.00 per tonne depending on volume, grain size and packaging.

Given that the raw limestone (ie. Pinehouse deposit) would have to be mined using underground methods, it is likely that cost of production would be higher in Saskatchewan than at other western lime producers which are extracting their raw material via surface mining operations.

6.1.2 Cement

6.1.2.1 Uses and Specifications

The term cement is used to designate many different kinds of substances that are used as binders or adhesives. The cement produced in the greatest volume and most widely used in concrete for construction is portland cement. The essential feature of this cement is its ability on hydration, to form relatively insoluble bonded aggregations of considerable strength and dimensional stability.

Cement is manufactured by processing and proportioning suitable raw materials, burning in a kiln, and grinding the resulting hard nodules called clinker to the fineness required for an adequate rate of hardening by reaction with water.

Usually two types of raw material are required for this process: one rich in calcium, such as limestone; the other rich in silica and alumina, such as clay or shale. A small amount of calcium sulfate in the form of gypsum is also added during final grinding to control setting time and enhance strength development. Portland cement consists of tricalcium silicate (45%), dicalcium silicate (27%), tricalcium aluminate (11%) and tetracalcium–aluminoferrite (8%), and gypsum (5%).

Since calcium oxide comprises about 65% of portland cement, processing plants are frequently located close to the source of calcareous material. The required silica and alumina may be derived from clay or shale. If needed the iron content is supplemented with iron ore, mill scale or pyrite

cinders. Silica may be supplemented by adding quartz rich sand to the raw mix, where as alumina can be furnished by Al_2O_3 rich clay.

The considerable flexibility in selection of raw materials for kiln feed lies mainly in the fact that cement making is a chemical process. Deposits of "cement rock" or impure limestone deposits which contain the correct balance of lime, silica, alumina, and iron, require virtually no addition of secondary raw materials to qualify as cement kiln feed. Such deposits are known to exist in the Hudson Bay area of Saskatchewan. Analyses of part of the speckled shales of the Favel and Vermilion River Formations along the Waskwei River approach cement rock in composition (Beck 1974). Subsequent investigations have indicated reserves in excess of 30 million tonnes of cement rock are minable by open pit with a stripping ratio of less than 1:1.

The numerous specifications regarding the processing and physical characteristic of the various types of cement which are produced are beyond the scope of this report. The Canadian Standards Association should be consulted for details regarding particular specifications.

Essentially all cement is used as a minor component of concrete. The status of construction activity largely determines how much concrete is used and how much cement is produced and sold. Typical concrete uses include buildings, foundations, pavement, bridges, dams, and precast shapes.

6.1.2.2 Producers and Consumers

Currently in Saskatchewan the only manufacturer of cement is Inland Cement of Regina. They imports crushed limestone quarried at an open pit

at Mafeking, Manitoba. Gypsum is also brought in from out of province. The limestone is blended and ground with local sand, clay and iron oxide. This mixture is then fed through a rotary kiln which is fired by natural gas. The resulting clinker is ground together with gypsum to produce the finished cement. Inland produces various standard types of portland cement by varying the composition and fineness of the cement. Their products include: Normal Portland Cement (Type 10), High–Early (Type 30) Cement, Sulphate–Resistant (Type 50) Cement, Masonry Cement, and Oilwell Cement.

Detailed production figures are not available for the Saskatchewan market as Statistics Canada has not published these numbers since 1984 (Figure 9). However, Inland Cement's Regina plant has a cement grinding capacity of 375,000 tonnes per year. According to statistics Canada utilization of cement grinding capacity has been running at an average of approximately 64% for the period 1977–87.

The cement producing scene on the Prairies is dominated by two major companies Canada Cement Lafarge Limited and Inland Cement Limited. Canada Cement Lafarge, operate plants at Fort Whyte, Manitoba, Exshaw and Edmonton, Alberta with a total cement grinding capacity of approximately 2 million tonnes per year. Inland operates plants in Winnipeg and Edmonton as well as Saskatoon with a total grinding capacity of approximately 2.7 million tonnes. The Saskatchewan cement grinding capacity accounts for approximately 7.9% of the Prairie total. Manitoba and Alberta account for 18.7% and 73.4% respectively.

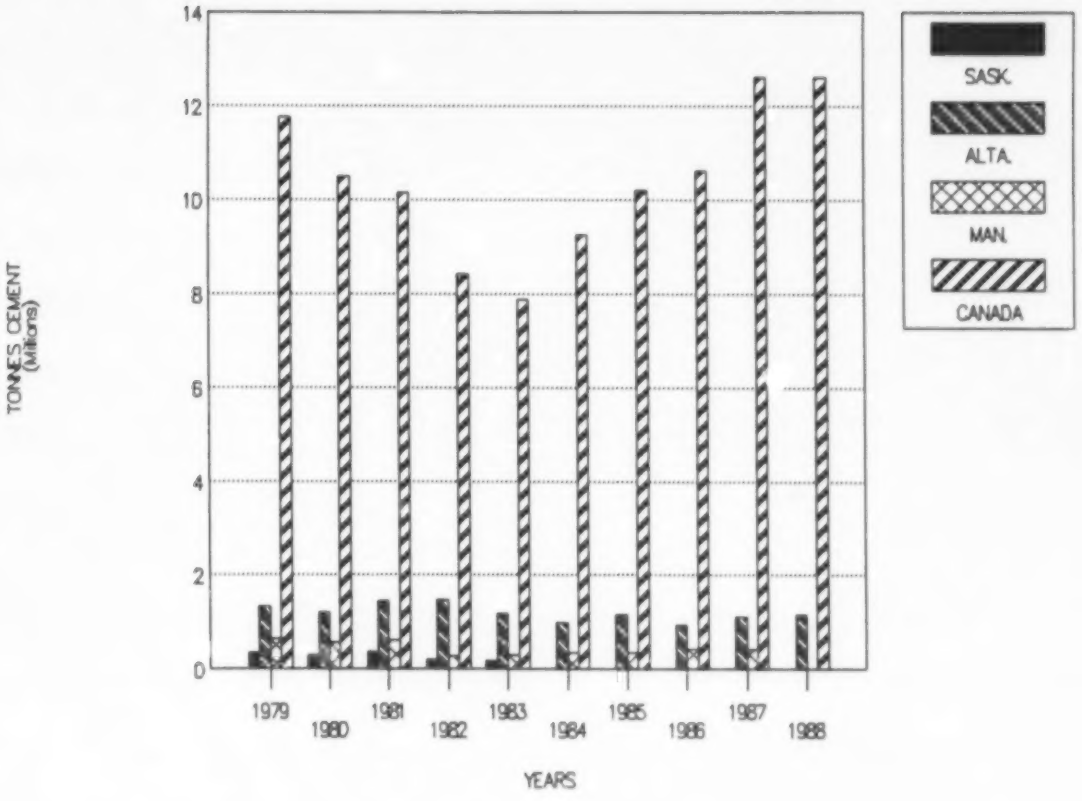

Figure 9. Cement Production

6.1.2.3 Markets and Prices

Major markets for Saskatchewan produced cement will be in the cities of Regina and Saskatoon. Other major urban markets in adjacent provinces are already served by local cement producers.

The price for delivered cement f.o.b. Regina was reported to average $140.00 per tonne in Saskatchewan. The bulk of the cement produced in Saskatchewan and imported from adjacent provinces is used in the ready mix concrete and concrete products industries.

Demand for cement is directly tied to the level of construction activity. The growth of the Saskatchewan construction sector will be a determining factor in the establishment of new or expanded cement production in the province.

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